Competency characterisation by means of work situation modelling.

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Abstract

Nowadays companies have to face the rapid evolution of their competitive environment. In the field of design, project managers are aware of both the impact of the designers' competencies on the project performance and of the requirement for a fast development of these competencies. However, they have difficulties in updating competency reference banks and then, in correctly matching the available competencies and missions that have to be performed. This issue of competence management mainly concerns competency allocation and project team building. In research literature, numerous research works suffer from poor competence modelling. Even if some authors have linked competence with work situation, there is often a lack of documentation concerning knowledge capturing about a designer's work situation which would help managers characterise competency. In this paper, we present the architecture of a novel approach based on the traceability of design activities which aims at assisting competency characterisation through qualitative features of the work situation in which this competency is activated.

Keywords: competency characterisation, activity modelling, project memory, knowledge capturing, competence management

1. Introduction

Nowadays companies have to face the rapid evolution of their competitive environment; new customer requirements to be satisfied, new technologies to be integrated into future products, new environmental and safety regulations to be respected, new computer-based tools introduced into design activities that become more scientific, new organisation structures, etc. In order to maintain a competitive advantage, companies have to be producers of distinctive competencies (Hamel et. al., 1994) [1]. It is especially in the fields of innovation and product development that managers are aware of the impact of the designers' competencies on the project performance and of these requirements for a fast evolution of these competencies. They have to identify and support all the processes which are involved in the development of these competencies.

Indeed, designing is a complex activity that generates new knowledge and that requires the integration of heterogeneous knowledge to transform a set of requirements and constraints into a technical artefact. The goals are often poorly defined at the beginning of a design project. As the project develops they are improved and become better defined as the technical solution is progressively refined in accordance with the modified design plans. Designers re-use and adapt their past experiences in order to understand the new problem they have to solve. They can then coordinate their work with their partners, to generate and evaluate different design alternatives, to explore and integrate new technical and scientific knowledge. These collaborative and creative activities can be facilitated with the use of appropriate tools such as CSCW (Shen et. al. 2006)[2], adaptable workflows, knowledge based systems (Studer et. al., 1998) [3] or project memory oriented towards design problem solving.

In the field of engineering design, companies are becoming more aware of the strong connection between competence management and knowledge management. But in literature, these research issues have been dealt with separately with only very few exceptions (Vasconcelos et. al., 2000) [4], (Berio et. al 2005) [5]. Until now, research projects on knowledge capturing in design have mainly focused on the traceability of results (e.g. requirements, drawings, reports), decisions (e.g. choices, alternatives, justifications), as well as the designer's logic to perform his (her) activity (e.g. design plans, rules). We think that the efficient development of new tools and methodologies that aim at integrating knowledge management and competence management, requires an appropriate analysis of both cognitive designers' activities and collaborative design situations.

In this paper, we propose a new approach to characterise competency. It is based on the modelling of work situations. We define relevant features of the work situation that are associated to qualitative variables in order to characterize the associated competency. Building a project memory oriented towards competency characterisation allows the development of a dynamic competency bank and is a first step to improving other goals of competence management such as competence allocation or project team building (matching of tasks and competencies), development and transfer of competencies (e.g. by supporting reflective practice).

In section 2, we consider the main characteristics of competency and goals of competence management through a brief literature review. In section 3, we present a general architecture for a method to assist in the characterisation of competencies. Section 4 develops UML models to represent work situations and to support knowledge capturing during an activity. Section 5 proposes the global model of competence while Section 6 gives examples of situation features and variables that can be used to link situation and competence components. Section 7 briefly describes the fuzzy characterisation of competencies that enables assessments to be made of the level of mastery in an acquired competency. An industrial case study is developed throughout the paper to illustrate each step of our approach.

2. About Competence Management

The awareness of the important role of competencies in the development of industry performance, Sohel et. al. (2003) [6] position this concept in an area for research applicable to different fields of study, such as sociology, psychology, industrial engineering, and computer sciences. In this part, we present different definitions of competence, goals of competence management and key research issues.

2.1. Definitions

Drejer (2001) [7] defines competency as: “a system of human beings, using (hard) technology in an organised way and under the influence of a culture to create an output that yields a competitive advantage for the firm”. Torkkeli et. al. (2002) [8] consider competency as the cross-functional integration and co-ordination of capabilities. Capabilities refer to the actor’s (or company’s) ability to exploit its resources. Le Boterf (2000) [9] points out that a competence is a construction, the result of a combination of cognitive resources from the concerned individual and of a network of resources from his (her) environment”. For Tobias et. al. (2003) [10], “competency is a set of personal characteristics (knowledge, skills, abilities) which are relatively stable across different situations”. Rosemary et. al. (2000) [11] define competency as “the degree to which individuals can apply the skills and knowledge associated with a profession to the full range of situations that fall within the domain of that particular profession”. Each of these definitions depends on the field it is related to and the specific needs it is addressing for that field. Despite their differences, these definitions highlight key characteristics of competency that are fundamental to understanding and emphasizing the close relationship between competence and work situation:

- Competency is a combination of various resources which goes beyond a simple possession of these resources;

- Competency is related to an actor that may be for instance, the company, a project team or an individual;
- Competency is supported by a cognitive structure that organises the way the activity is performed and that is relatively stable across a full range of situations;
- Competency is a construction because each time it is activated, it may be improved, enriched and developed to be adapted to the changing features of the situation but without getting out of the associated class of situations (competency is not a stereotype, even if its organisation is quite stable) otherwise a new competency may emerge.

2.2. Goals of competence management

Competence management should address all the processes that are involved in the production, implementation and development of specific competencies. It deals with managerial methods/techniques in such a way that there is an increase in the effectiveness of core competencies, either available to a firm or able to be developed there (Hamel et. al., 1994) [1]. In accordance with other authors (Berio et. al. 2005) [5], (Stenlund et. al. 1999) [12], we summarize the general process of competence management as covering the following goals:

- Competence identification which integrates all the processes concerning the inventory of competencies required by the business processes (with tasks and missions) and those acquired by the actors (e.g. the company's employees, the project teams).
- Competence allocation (or team building) which is the process of assigning various missions to human resources who possess different kinds of knowledge, according to defined management policies.
- Competence acquisition which involves recruiting, selecting and hiring people to meet the company's present and expected needs for competencies.
- Competence mobilisation which concerns the managers' practices of setting up favourable work conditions in order to enable human resources to achieve their missions.
- Competence development which involves various forms of training and learning on-the-job (e.g. reinforcement of existing competencies, emergence of new competencies). It aims at maintaining competencies within the firm and is supported by the capitalisation process and the employees' motivation to work within the firm, in order to guarantee the availability of competencies.

- Competency characterisation which aims at formalising competencies and storing key features that will be re-used as data by the other goals of competence management.
- Competence evaluation (or assessment) which is closely linked to competence identification and characterisation. It implies that the evaluation committee has to be made known beforehand and that the goals to be reached, the success criteria (is the actor competent or not?) and the performance indicators have to be well defined. The evaluation concerns the comparison between the goals and the results and sometimes, the way the actor has performed his (her) activity (respect of procedures).

In recent years a number of formal methods have been developed in industrial engineering to facilitate the work of decision-makers in their management of projects and human resources (Tsai et. al., 2003) [13], (Chen, 2005) [14]. Several methods are based on the formalism of fuzzy logic, initiated by Zadeh (1965) [15]. This choice is understandable because of its flexibility for modelling qualitative and abstract aspects as well as the imprecise nature of human speech. This characteristic assumes that an expert's decision-making and evaluation procedures can be approximated by a set of inference rules.

Pépiot et. al. (2005) [16] propose a method, based on fuzzy logic, to recognize the value of competencies that are crucial to a company. The authors have developed a formal model of competence, which includes an evaluation of its resources through four indicators (value, scarcity, imitation and replacement).

Some authors are interested by the goal of competence allocation and team building (Canos et. al. 2004) [17]. De Korvin et. al. (2002) [18] propose a technique to help select project team members in accordance with the desired objectives and the competencies the organisation already has. The method is based on a imprecise measure of the compatibility between the competencies available and the activities of the project.

In addition to the list of goals given above, the management of the process of competence management itself can be added. Boucher et. al. (2003) [19] have proposed a method to evaluate the performance of competence management processes through the development of specific indicators. It aims at giving managers a decision support system by assessing the results of different action plans to obtain the appropriate development of competencies. This approach is based on a fuzzy modelling of competency, linked to professional situations, actors and resources.

In the references discussed above, competence is generally used either without formalising its resources or with the assumption that an external analysis could succeed in assessing its resources. However, this assessment is highly subjective. An important task of competence management is competency characterisation that consists in formalising the competence and determining its key components as well as the situation features that link a particular competency with the actor's activity. The identification and indexing of competencies involves organising them in reference systems. Creating this type of reference bank is done by HR (Human Resource) experts who analyse the requirements of the work situations (Rault-Jacquot, 1993) [20]. However, the rapid evolution of the actor's environment means information recorded in this type of reference system quickly becomes obsolete and needs frequent updating. Some research projects cover the development of information systems specifically for the formalisation and use of competencies (Harzallah, et. al., 2006) [21]. According to Vidal et. al. (2002) [22], a global approach to the characterisation of competencies through work situations should follow the following stages:

- Collection of data about the operator's activity through questions representing the situation and classes of situations.
- Analysis of events dealing with a specific situation and the functioning of the operator's cognitive model in that particular situation.
- Development of different connections between the kind of situation and the competency.
- Definition of the competencies required and then, construction of a reference system.

Our research has been conducted in this context. Our work concerns competency characterisation through the analysis of work situations using UML models and the fuzzy logic theory to make the connection between competency and situation (traceability of design activities). Our approach aims at approximating the reasoning of the expert in charge of competence management so that this activity can be at least partially programmed and a dynamic aspect (regular updating) can be integrated into competency banks.

3. Analysis of work situations as a tool for competency characterisation

The theoretical background at the base of our approach, has been developed in previous works (Bonjour et. al. 2002) [23] and has proved consistent with the scheme theory (developed by J. Piaget) both by practical experience at a French car manufactory and by discussions with G. Vergnaud (Vergnaud 1998) [24], a specialist of this theory and who has collaborated with J. Piaget. Le Boterf has already drawn his readers' attention to the relevance of this theory in order to better define and formalise competence (Le Boterf, 2000) [9]. The next section briefly presents this theoretical background, the global architecture of our approach and the industrial case study that will be used to illustrate our approach.

3.1. A theoretical background

The definition we have chosen for competency is as follows (Bonjour et. al., 2002) [23]: “Competency is the mobilisation and dynamic organisation of a set of heterogeneous cognitive resources that leads to the production of an acknowledged performance, in relation to a given situation and in the context of a finalised activity”. Thanks to his competency, an actor performs a task with which he has been entrusted through a successful flow of action that will achieve the results expected. We have already presented an approach based on the system theory to define and model an actor's competency (Bonjour et. al, 2002) [23]. This model includes, on the one hand the nomenclature of the constitutive elements and, on the other hand, the structure of interactions between elements. The competency modelling is a matter of a fundamental cognitive approach and we rely on the scheme theory, initiated by J. Piaget (Vergnaud, 1998) [24]. Interactions between the situation and the actor are the base of the scheme. The actor modifies elements of the situation, and through a feedback loop, elements of the situation modify and enrich the actor’s representations of the situation. A scheme is specific to an actor. It is an open, evolving system that corresponds in the future to a potential for action in similar situations.

3.2. Knowledge, situation and competency

Thanks to the definitions given above and our theoretical background, the following remarks can be made about competence and its connections to knowledge and situation.

First, competence can be differentiated from qualification as it cannot be identified independently from performance in a finalised activity. Consequently, the understanding of competency will come from analysing the activity that has activated it.

Second, knowledge is one of the resources of competence (Grundstein 2001) [25]. The process of competence development is always linked to the process of learning and the acquisition of different types of new knowledge, while the process of putting a specific competency into practice is accompanied by the activation of a certain amount of acquired knowledge. This includes knowledge concerning key entities (e.g. type of task, type of resource) that allow the actor to link the current situation to situations in the past, as well as knowledge such as action rules.

The third aspect concerns the close link between the competency and the work situation in which this competency will be used (Le Boterf, 2000) [9]. The scheme activation aims at achieving goals related to a class of situations and results in a relatively stable organisation of the associated action plan for such similar situations. This aspect means that signatures specific to each competency can be elaborated through their underlying scheme.

These points are the basis of our approach. Its architecture is briefly presented in the following section.

3.3. Architecture of our approach

Figure 1 shows the architecture of our approach that is consistent with the stages proposed by Vidal et. al. (2002) [22]. It includes three basic modules: knowledge capturing, situation characterisation and competency characterisation. Each module is connected to a specific model that supports database structuring and processing.

Insert here Fig. 1: Architecture of our approach

The architecture is as follows:

- The first module called "knowledge capturing" is a system for the traceability of design activities. It allows for information to be provided regarding the different aspects of the environment in which it takes place, the organisation of the activity, the constraints and the relationships between actors. It provides information about the modifications made to the situation as a result of an activity. Situation models and activity models give a structured presentation of data concerning this module and will be developed in section 4.
- The second module called "situation characterisation" contains new elements of knowledge about a situation deduced from a set of relevant situation features. These features are associated to qualitative variables for the need of competency characterisation. This module will be shortly detailed in section 6.
- The third module called "fuzzy characterisation of competencies" is based on a fuzzy system. It uses inference rules to approximate the expert's reasoning. Formalisation of the different connections between situation and competency allows the characterisation of the competency components that are structured according to a competence model that will be presented in section 5. This competence model is used as a basis for structuring data (output of the fuzzy system that is the assessed value of

competency components) in the competency reference bank. This module will be discussed in section 7.

Note 1: we need to introduce the model of competence before defining qualitative variables because these are specified according to the competency components.

Note 2: The situation models we propose could be used to structure data in a project memory to support the designer's activity in the solving of similar problems in the future (a goal of knowledge management).

3.4. Industry case study

To illustrate and test our approach, we monitored a design project in a big firm that manufactures furniture and distributes its products through a sales network. This case study allowed us to closely assist designers and managers (specifically, the conceptual design manager and the embodiment design manager), with weekly debriefings about the strengths and weaknesses of our approach (e.g. discussion of the data books and about the granularity of information).

The project was to design a new type of TV stand that was suitable for the new types of television (LCD and plasma screens) and that offered a significant and functional added value. The design process was divided into three main tasks and so the project took place in three phases:

- Market research, analysing what was already available and identifying the customers' requirements;
- Proposal of innovative concepts and elaboration of sketches;
- Development and production of a prototype, and a cost estimate.

Each phase was monitored by a project review (justification and evaluation of decisions). The designers' proposals were accepted during the final project review. The agreed proposal then proceeded to the manufacturing phase (detailed design and production preparation).

4. The module “Knowledge capturing” and situation models

The module “Knowledge capturing” aims at capturing information concerning the history of the realisation of activities which is structured according to situation models and activity models. Researchers in artificial intelligence and knowledge management are interested in producing models and tools for the representation of context knowledge and the re-use of them in problem-solving applications (Oztürk et. al., 1998) [26].

In previous publications (Belkadi et. al., 2004) [27], we defined a work situation as "*a set of various entities and of various interactions (of different kinds) globally describing the external environment in which an actor mobilises his competencies*". We propose to represent the work situation using three main concepts: basic entities, interactional entities and specific roles. Entity is a generic concept that is used to represent all the physical elements of the situation (basic entities) and the interactions between these elements (interactional entities).

4.1. Basic entities (BE) or concrete entities

These entities bring together the different physical elements in a situation which includes all the human actors (called individual entities), and the material resources (called physical entities). Some examples of material entities in a design project are: drawings, specification documents, CAD tools, communication tools and management tools.

4.2. Interactional Entities (IE) or abstract entities

These refer to links between entities in a given situation. We define four forms of Interactional Entities (IE) as follows:

- "Operational Interactional Entities" inform us of all the possible transformations in a situation. They refer to specifications which have an effect on objectives and also, to the activities that are performed.
- "Community Interactional Entities" describe a link of affiliation between parent and child entities. Generally speaking, the notion of belonging to a community is expressed through shared rules (e.g. a process could be considered as a community IE that puts together different tasks with specific sequence rules). Value and culture are specific to Human community IE (e.g. a project team is a community IE that puts together different human resources that share the same goals and some values). Collective competencies can be associated to a community IE.
- "Transactional Interactional Entities" denote various mechanisms of information exchange or the exchange of material resources between human resources during the carrying out of their collective tasks (e.g. a project review meeting is a transactional IE that involves several actors, each actor playing a "specific role" during the meeting)

- "Constraints" express, in a general way, requirements and limits on the realisation of an activity or on a given interaction (e.g. a constraint may be "after each project review meeting, a report must be written").

4.3. Specific roles

The definition of a work situation should not only take into account the enumeration of its different elements and the relations between them, but also the nature of the contribution made by each entity to the interactions. The concept of role has been the subject of many definitions and studies, depending on the discipline (sociology, organisation theory, and information sciences are some examples). Sübmilch-Walther (2002) [28] refers globally to a set of behaviours used by an individual relative to his position in the organisation. Uschold et. al. (1998) [29] defines role as the way in which an entity participates in a relationship with one or more entities. In our approach we propose systematically to adapt the concept to extend it to all the interactions in a work situation. Each entity plays a specific role in a given interactional entity. We distinguish five kinds of specific roles as follows:

- The "actor" role answers the question “who does what?”, ‘what’ being an IE. It concerns every entity who/which participates directly in the interaction and who/which is responsible for the end result (in the case of cognitive actors).
- The "customer" role answers the question “For whom?” It brings together all the entities that are going to be receiving the end result of the IE.
- The "manager" role answers the question “How?” It concerns every entity who/which regulates the functioning of an IE.
- The "support" role answers the question “With what?” It includes every entity who/which assists in its realization.
- The "object" role answers the question “About what?” It concerns every entity on whom/which the IE acts.

4.4. Meta-model of the situation

According to the definition given above, the meta-model of the situation framework is described in an UML class diagram (Figure 2) by a set of entities and roles. Any object of the entity class can be related to any other object of the interactional entity class, according to a specific role, which is described as an instance object of the class “specific role”.

Insert here Fig. 2. The Meta Model of the Situation

4.5. Activity organisation

Activity is described in an environment known as "the realisation environment" according to a given mission. It is of an operational nature and it is defined as a set of physical and mental actions, by which the actor implements all material and informational resources he has to deal with in the current situation he has to face in order to fulfil the mission that has been entrusted to him.

4.5.1. The mission view

The mission view contains a task (considered as an operational IE), that contributes to a set of goals and is linked to different entities:

- The expected object of the task and possible supports.
- Human resources and constraints playing the role of manager.
- Other contextual elements that are important to define the mission more properly (task framework).
- The subsequent task in the corresponding process. This task plays the customer role.

Insert here Fig. 3. The mission view

4.5.2. The model of activity realisation

The view of the activity associated with the carrying out of the mission includes the object, manager entities, and in addition:

- The actor, who is either a human resource or a community IE (e.g. a department, a project team).
- The intermediate objectives or results that are expected to be either produced or treated.
- Additional support (that is, material or informational resources).

Figure 4 shows that each task is carried out by an activity according to an action plan. At the beginning, the cognitive actor defines his action plan (recorded in release 0), completely or partially. The action plan contains a set of sequential actions (or partially sequential). The result of each one will be the creation, the deletion or the modification of one or more entities in the situation. During the activity, several modifications may be observed in the action plan (each modification is recorded in a new release). These modifications are the results of either new events not envisaged at the beginning, or the presence of new constraints, generated by the activity in question or, by the activities of other cognitive actors. The action plan (a sequence of planned sub-goals) gives a representation of the cognitive organisation of the activity. It is a description of the manner in which the actor expects to reach the task goals.

Insert here Fig. 4. The model of activity realisation

4.5.3. The action view

Every modification to the action plan structure implies either the creation of a new external action (e.g. analysis, or evaluation), or the deletion of some of the actions or changes in the sequences. These modifications are the result of the presence of new constraints or new events. In order to approximate the cognitive functioning of the designer (the actor in this case), we have searched for a typology of elementary actions. By studying several key references in engineering design (Pahl 1996 [30], Chandrasekaran 1990[31]), we propose five kinds of actions that can cover all aspects of the designer's activity:

- Analysis/Understanding: The aim of this action is to extract information and knowledge from the studied object (or problem). The result does not affect the state of the studied entities.
- Search/Generation: It is an action that consists of creating and generating new ideas, new concepts, new hypothesis, new constraints, and new principles of solutions in order to solve the problem. This kind of action affects the situation by creating or modifying entities. These new entities subsequently require evaluation and validation.
- Evaluation/Assessment: This action gives information about the properties or behaviours of an entity or sub-entity regarding certain criteria. For instance, in NPD, analysing sensitivity or robustness is useful to correlate requirement variables and solution parameters, with the use of scientific knowledge. This kind of action can help the actor to justify the former hypothesis and concepts.
- Choice/Decision-making: The action of decision has an effect on the state of at least one entity. The decider validates (or not) the propositions in accordance with the results of previous actions and chooses the best solution among certain variants regarding his goal and related constraints.

- Execution/Treatment: This category deals with all the actions that will produce physical or informative transformations on the object. It has a direct effect on the state of at least one entity, for example, the determination of a parameter value, the resolution of an equation, or simulations.

These elementary actions are used to describe each activity with its associated action plan.

4.6. Case study

The object diagram in Figure 5 shows an instance of the class diagram related to the mission view (presented above in Figure 3) for the project that consisted in analysing the existing TV stands. This mission took place during the market research phase whose goal was to determine both the target market and the current trend for the TV stands (with market forecasts over a 3 year period). This trend has to be correlated with the expected evolution of the TV market for flat and large screens. Specific TV stands could satisfy the requirements of customers who would buy these types of TV.

Insert here Fig. 5 Instance of the mission view

The object diagram of the associated activity is presented in Figure 6. This figure looks like Figure 5 with the difference that the “activity object” is associated to an “actor” role and contains more details. In this case study, the actor of this activity is a community IE which includes four human resources (two designers playing the role "actor", one manager and one support).

Insert here Fig. 6: Instance of the activity view

Figure 7 represents the organisation of the activity (according to the action plan) and the realisation of the task "Analysis of the existing products", more specifically TV stands (according to elementary actions):

Insert here Fig. 7: Example of a model for an action plan: analysis of the existing products

Two remarks can be made about the model in Figure 7:

- During the activity, several intermediary objects were designed that were not included in the final results but were necessary for the formalisation of the competencies that had effectively been mobilised in the activity.
- The action plan was slightly modified during the activity (repetition of the sequence {AI1.4; AI1.5} in the sequence {AI1.8; AI1.9} to fine-tune the findings), which led us to identify this activity as being quite stable.

5. Towards a model of competence

We needed a model of competence to be able to structure the competency bank and to support the module "fuzzy characterisation of competencies".

5.1. Global model of competence

In accordance with our theoretical background, we modelled competences in an UML class diagram (Figure 8). In this model, a competency is either acquired by an actor and then supported by a scheme, or required by a task and described by the mission. A scheme corresponds to a cognitive structure that supports the achievement of an activity. There may be several schemes underlying the same competency (different ways of operating depending on whether the actor is either a human resource or a community IE). A model of a scheme is composed of a set of technical knowledge, cognitive capacities, action rules and a class of situations (matching a set of similar situations) in which the scheme is efficient. We define missions with properties that allow a set of missions to be brought together according to the abstraction level that is judged appropriate to refer to a particular scheme. Recommendations about the mission definition will not be treated in this article.

Insert here Fig. 8: Global model of competence

5.2. Components of competency

We propose to describe a competency through a set of technical knowledge linked to levels of mastery and a specific signature of competency with respect to cognitive capacities and action rules.

5.2.1. Technical knowledge

In reference to the situation model presented in Figure 2, we propose to classify technical knowledge according to the role that an entity plays in either the mission view or the activity view:

- Operational knowledge: is related to what is needed to perform a task (such as, knowledge and skills acquired in training or through experience), to a correct understanding and interpretation of all the prerequisite information about the specifications of the mission, and also to reading, understanding and interpreting technical materials on required standards and on unavoidable constraints.
- “Object” knowledge: is related to needs in dealing with entities having an object role in the interaction. It is related to the domain of the object itself (such as, specific knowledge about the domain).
- “Support” knowledge: is related to needs in dealing with the entities having a support role in the interactional entities (such as the instruction manual for tools or safety instructions).

5.2.2. Cognitive capacities

Cognitive capacities can be qualified in relation to the complexity of a task and the context in which it is carried out.

- Cognitive capacities - "Analysis/Understanding". This category is concerned with capacities for perceiving and analysing a current situation, and being capable of extracting information that is relevant to one’s work during an interaction with the situation.
- Cognitive capacities - "Organisation". This category relates to the effort required by an actor to organise his work and resources and to prioritise the various actions constituting the activity.

5.2.3. Action Rules

These are concerned with aspects related to performing tasks in a changing situation that necessitates either reactive or collaborative actions:

- Decisional aspects: The reactive aspect refers to the capacity to react when faced with unexpected events in the situation, and to be able to make the right decisions in a complex situation.
- Relationship aspects: The relationship aspects are concerned with all the actor’s behavioural aspects when he plays a specific role in either a transactional IE or a community IE, during the activity.

5.2.4. A cognitive signature of a competency

We define a cognitive signature of a competency according to both the cognitive capacities and the action rules (figure 9).

Insert here Fig. 9: A cognitive signature of a competency

5.3. Case study

Let us consider the case of a designer recently hired by the company. He was recognised as having the following (acquired) competency:

- Being able to analyse the current furniture market and to present his market research report with representation tools of the market segmentation.

Let us consider a mission (required competency) that could be expressed as follows:

- to be able to analyse existing TV stands in the current market and to present the market survey report with visual and meaningful supports that clearly show the trend of the target market.

The manager has to assess whether the designer is able to further develop his (her) competency to achieve the mission and how to train or assist this designer in order to make this development easier. In fact, the main point was to develop technical knowledge related to the specific "representation tool " for the market survey report.

For the identification of the competency components, the mission view has to be used, especially to identify the technical knowledge required. The description of the goals is linked to the operational knowledge:

- To be able to draw up an inventory of existing TV stands and more specially, for flat screens. Information must come from different sources (e.g. catalogues, web sites, visits of furniture chain stores).
- To be able to represent the market survey with specific representation tools that help elaborate visual and meaningful supports

- To be able to define relevant criteria to classify existing furniture (e.g. functions, colours, materials, shapes, sizes, prices). This operational knowledge is required in order to succeed in designing the appropriate supports for the market survey.

The object knowledge is identified from the objects in the instance of the mission view:

- To know the main functions, conditions of use and features of furniture, and in particular of TV stands. This knowledge was non-existent in the beginning and was progressively enriched during the activity.

The activity view helps identify support knowledge that is necessary to handle the entities playing the support role:

- To be able to elaborate, use and update a realistic planning so as to respect the dead line date.
- To be able to analyse and understand "technical and marketing files" related to furniture manufactured by competitors, obtained from various sources of information.
- To be able to use a specific representation tool to structure the market survey with visual and meaningful supports (e.g. drawing)

Concerning the cognitive signature presented in 5.2.4., we have developed an example related to the "analysis" capacity in the following sections.

6. The module “situation characterisation”

6.1. Definition of situation features

The values of the different attributes of the target competency depend, to a considerable extent, on the features particular to the situation in which the competency is mobilised.

Insert here Table 1. Relationship between situation and competency

As an example, we can suppose that the organisational effort necessary is in direct proportion to the number of elements the actor has to take into account in order to carry out his activity. The table above sets out a list of the possible situation features that have been selected to link the work situation and the competency mobilised.

The evaluation of the different features which characterise a situation is rather qualitative, and it depends principally on the general context of the person making the assessment. For example, an expert could consider that the number of participants in a cooperative action is high, if the number is higher than 8 and the total number of staff present is 10. This evaluation would of course be lowered if there were the same number of participants in a setting, where there were actually 50 active staff members.

6.2. Characterisation of situation variables

New variables can be linked to the preceding features and they can be used to characterise the situation (table 1). These variables may have quantifiable values such as the number of interactions during the activity or the number of constraints. They are selected and defined depending on the need for treatment and on the desired degree of detail.

For example: the feature “nature of the activity” which is associated with the capacity "analysis / understanding", is qualified by the variable "Proximity_analysis". This variable is estimated through the number of elementary actions present in the studied activity. Each type of the elementary actions (defined in section 4.5.3) is weighted by a proximity factor with the analysis capacity:

Analysis: 1 ; Search: 0.90 ; Decision-making: 0.60 ; Evaluation: 0.50 ; Execution: 0.20

The variable "Proximity_analysis" is assessed with this formula:

Proximity_Analysis (activity x) = $\sum_{1..5}$ (proximity factor) x (% of presence in the activity) (*)

where "% *of presence in the activity* " means the number of times an elementary action is present in the action plan.

Similarly, the complexity concerning the activity object is represented according to two criteria: the aspect of the object and the aspect index as follows:

- Aspect =: {conceptual, functional, behavioural, structural, geometric}
- Aspect index = (number of aspects involved)/(total number of aspects treated)

As with the nature of the activity, weightings are associated with each of the aspects of the object according to their respective importance: 1; 0.75; 0.50; 0.25 for (conceptual or functional), behavioural, structural, geometric respectively.

The general formula to calculate the value of complexity (CplxObj) of the manipulation of the object is:

CplxObj = [$\sum_{1..4}$ (weighting) x (aspect index)]

The proximity factors and weightings have been discussed and estimated with a HR expert.

6.3. Case study

The action plan, described in section 4.3.3, for the activity "analysis of existing products" during the "market research" phase contains the following nine elementary actions :

- 1 analysis action / 9 i.e. a presence factor of 11.11 %
- 1 search action / 9 i.e. a presence factor of 11.11%
- 1 decision-making action / 9 i.e. a presence factor of 11.11%
- 2 evaluation actions /9 i.e. a presence factor of 22.22%
- 4 execution actions /9 i.e. a presence factor of 44.44%

The value of the proximity between the activity called "analysis of the existing products" and the "analysis capacity" equals: Proximity_analysis(**ACT1**) = 0.462

The main object here is the TV stand. An analysis of the current offer was conducted by first checking the inventory and then by categorising furniture in terms of both its general and its geometric structures. The sale prices were also taken into account and are considered here, to put it simply, as a parameter of a geometric model. This is generally 1/3 of the structural aspects and 2/3 of the geometric aspects (N.B. to be more accurate, the type of aspect involved can be considered for each action of the action plan).

The value of Cpl x Obj = (0.50 x 1/3) + (0.25 x 2/3) = 0.333

7. The module “fuzzy characterisation of competencies”

The method we propose is based on the principles of a fuzzy inference system (Dubois 1991) [32], made up of three basic stages as shown in Figure 10. In this section, we present some of the points developed in our method through examples taken from the industry case study presented above.

Insert here Fig. 10: Fuzzy system of competency characterisation

7.1. Fuzzification

The “fuzzification” stage involves associating linguistic variables with different situation variables and representing them through membership functions $\mu_a(x)$ that express the estimation given to the value of a variable, considering that it belongs to a particular group. Trapezoids were chosen for the membership functions with the relevant linguistic variables. The definition of these membership functions reflects the expert’s preferences.

7.1.1. Case study

We have chosen three fuzzy values for the linguistic variable “nature of the activity” discussed above. They are: different, "relatively close", and close (see figure 11). Similarly, the value of “proximity/analysis” (0.462 or 46.2 %) is considered "relatively close" with a total membership degree $\mu_{RP}(Ac) = 1$.

Insert here Fig. 11: Membership function of the variable "Proximity / Analysis”

For the variable "complexity of manipulation of the object", the membership function is represented by a trapezoid (Figure 12): For the activity “analysis of existing products”, the main object is considered to be simple with $\mu_S(Ob) = 0.45$ and "relatively complex" with $\mu_{RC}(Ob) = 0.55$.

Insert here Fig. 12. Membership function of the variable “complexity of the situation”

7.2. Inferences system

The inference system approximates the way an expert in the field finds a solution to a problem. It includes a set of rules (**If** antecedents **Then** consequence) as shown in the following example of the case study (see rules 4 and 5 later):

(IF Proximity_Analysis IS relatively close AND Complexity IS simple THEN level IS D2) OR

(IF Proximity_Analysis IS relatively close AND Complexity IS relatively complex THEN level IS D3)

The inference mechanism links the operation min (μ_x(antecedent i), μ_y(antecedent j)) to each of the logical operators "AND". The operator "THEN" indicates the inference result of the rule and it is linked to the operation min(μ(result_antecedent) , μ(consequence)). The different operators "OR" between the different rules are evaluated by the operation max (μ(results of the rule)). Here "antecedent" covers the various situation features, while "consequence" contains an evaluation of the component of the competency in question.

There are two variables in the definition of the component "analysis capacity". The rules below (in Figure 13, issued from Matlab Toolbox) show the relationships between these descriptive variables ("proximity_analysis" and "complexity") and the analysis capacity.

Insert here Fig. 13. Inference rules

Note: The output of the membership function in the case of the component corresponding to the cognitive capacity "analysis/understanding", is triangular-shaped and on a scale of 10 with four linguistic variables expressing the level of mastery of this capacity:

- D1 Basic: Observe and identify sources of information,
- D2: Find interesting items and connections between them in the sources of information,
- D3: Understanding and visualizing these items and relationships,
- D4 Experienced: Synthesize and deduce.

7.2.1. Case study:

The case study presented here uses four inference rules {4 ; 5}. The application of fuzzy inference operators to the first rule produces this result:

Min (μ_{RP}(Ac), μ_{RC}(Ob)) = min (1; 0.55) = 0.55

The membership function that is the result of rule 5 is shown in figure 14:

Insert here Fig. 14. The membership function of the result of rule 5

7.3. "Defuzzification"

The final stage involves finding a value for the competency from the resulting membership function. The two main methods used in research literature are either the "centre of gravity" or the "max". The centre of gravity method is used here. It entails calculating the surface included between the membership function, which is the result of the output of the inference motor, and the x-axis. The general formula for "defuzzification" by the centre of gravity is given in the ratio below:

$$x_r^* = \frac{\int_S x_r \mu_r(x_r) dx_r}{\int_S \mu_r(x_r) dx_r}$$

The output value correlates with the linguistic value relative to the value of maximum membership for the *x*-axis of the centre of gravity.

7.3.1. Case study :

The membership function that is the output result of our example has the shape shown in figure 15:

Insert here Fig. 15: Assessed value of the "analysis level" after defuzzification

The value of "defuzzification" in our case study is 5.09/10 over x. This value is considered as a D2 level and D3 level with, approximately, the same membership value. The level of the analysis capacity for this activity is at least D2 and therefore not very high. According to the Head of the design department of this firm, this is consistent with the work the designers actually did in this activity. Their work involved taking the information about current products, then putting it into categories according to the subject (on the drawing-board) in order to bring out what was at the core of the product range.

8. Conclusion and future works

Starting from the fundamental hypothesis according to which competency cannot be defined independently of the activity and its situation, we have proposed a general approach to the characterisation of competencies through the features of work situations. Our main aim here has been to show how to use knowledge about the work situation for one goal of competence management, which is competency characterisation. The generic concepts of entities, interactions and specific roles provide the model with a great adaptability for the representation of different types of situations, depending on the field of study. These concepts are used to get a qualification of the situation features. The choice of inference rules and of situation features is neither exhaustive nor final. It can be adapted to the manager's needs and to the particularity of the concerned activity. This characterisation is, however, limited in that there are no standards suited to every kind of situation. This means that expertise in the field is very important in the early stages of modelling.

Our work is open to improvement and to being tested. We are currently interested in ways of assisting decision-making and classification, in order to have more specific details about the situation features by integrating information from a record of similar past activities. Systems such as CBR can be used to produce dynamic reference systems of competencies, taking into account the changing demands of work situations in terms of the definition of the components of competence. This work also opens perspectives for research into approaches to team building (choice of team members being based on their competencies).

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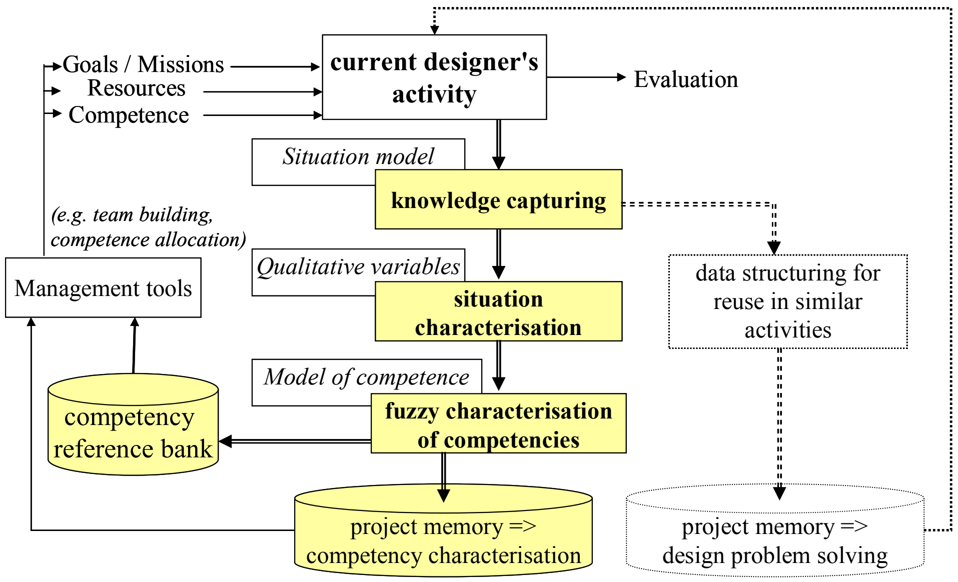

Figure 1: Architecture of our approach

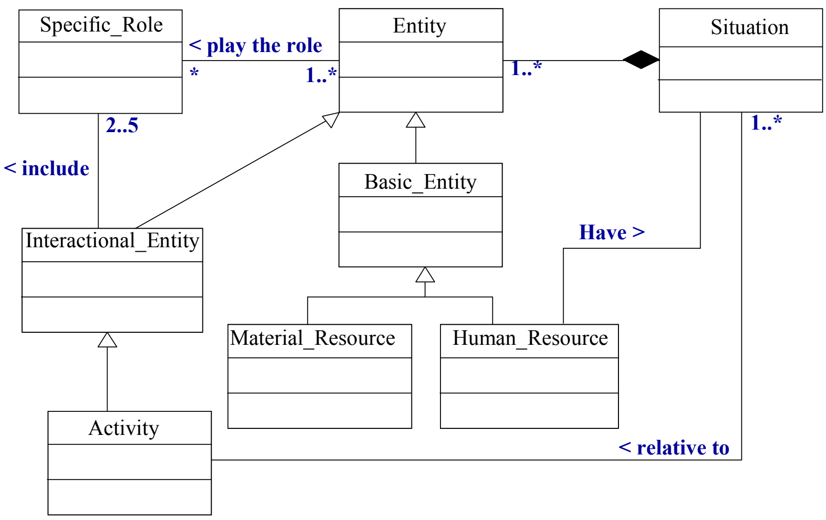

Figure 2. The Meta Model of the Situation

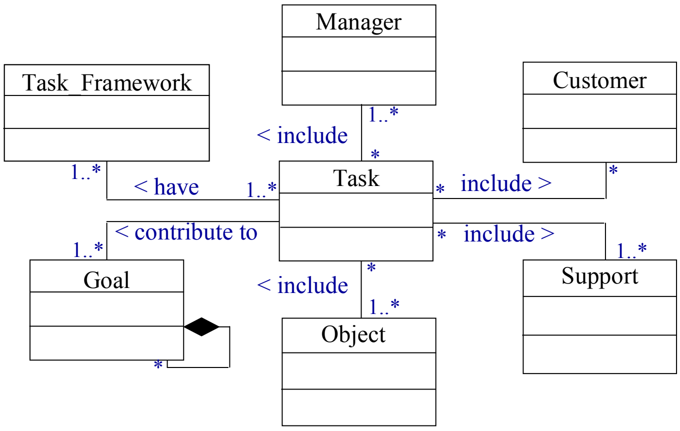

Figure 3. The mission view

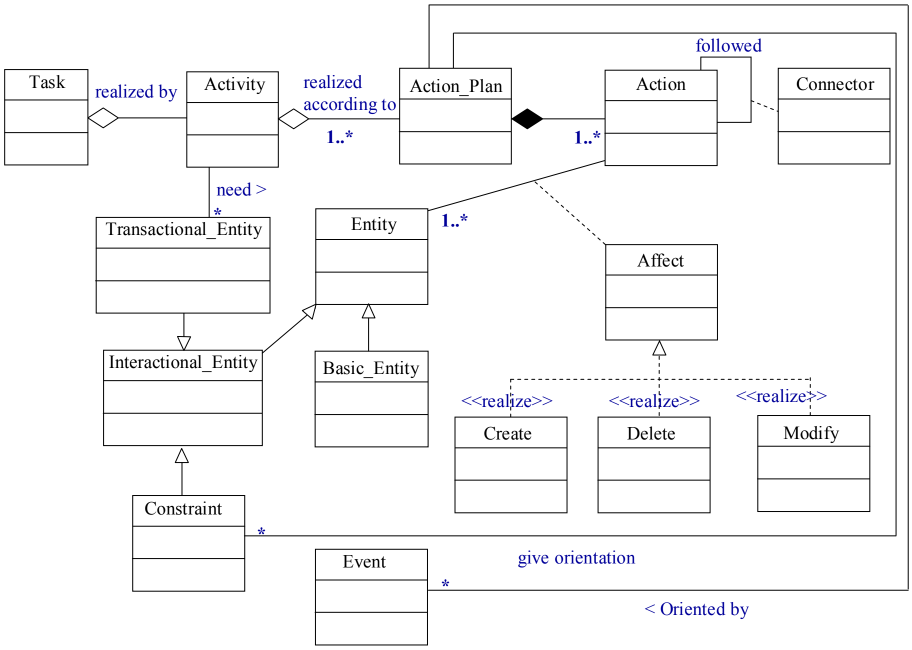

Figure 4. The model of activity realisation

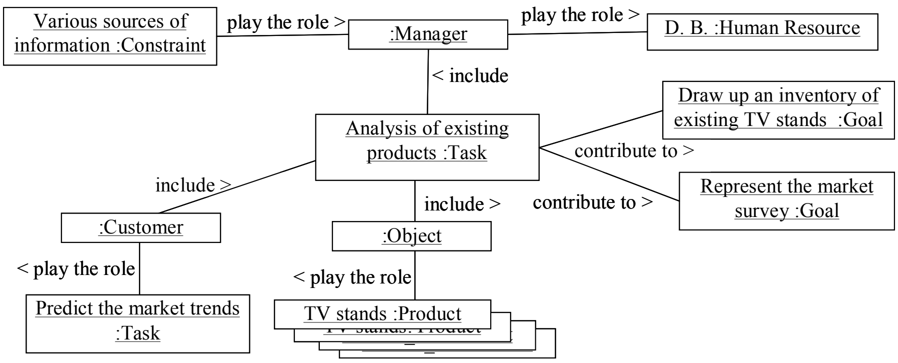

Figure 5 Instance of the mission view

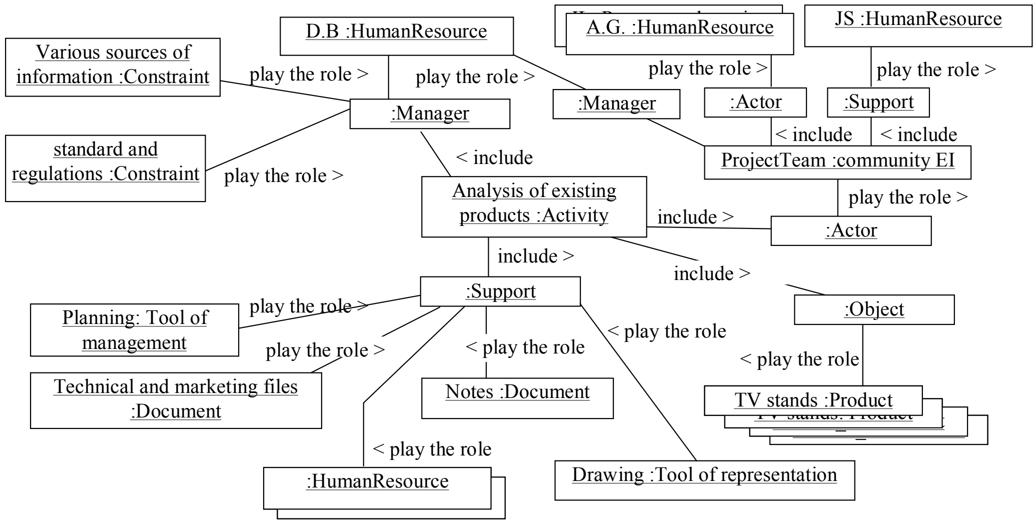

Figure 6: Instance of the activity view

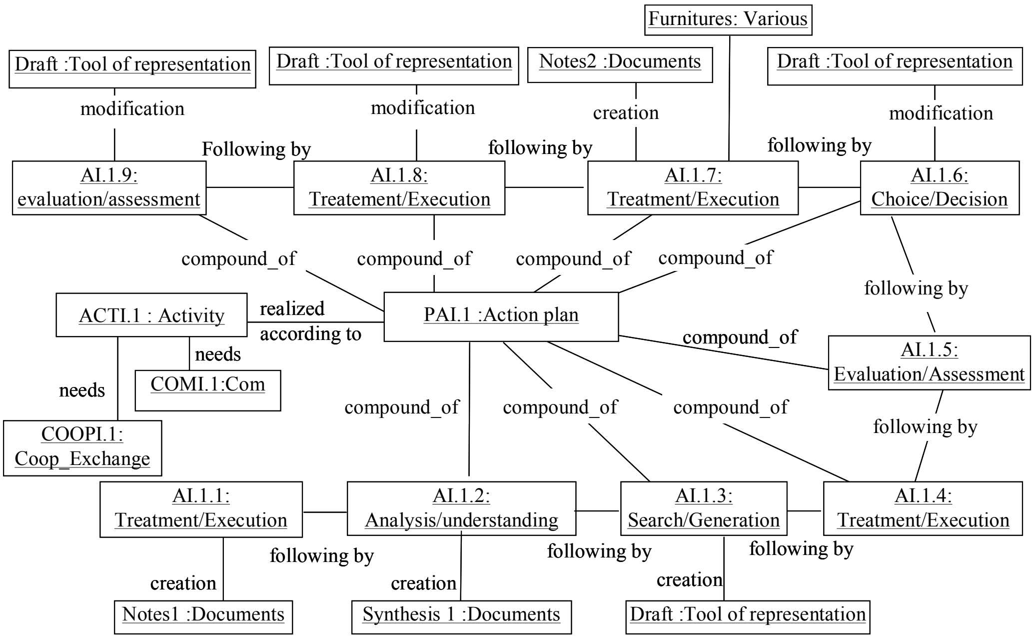

Figure 7: Example of a model for an action plan: analysis of the existing products

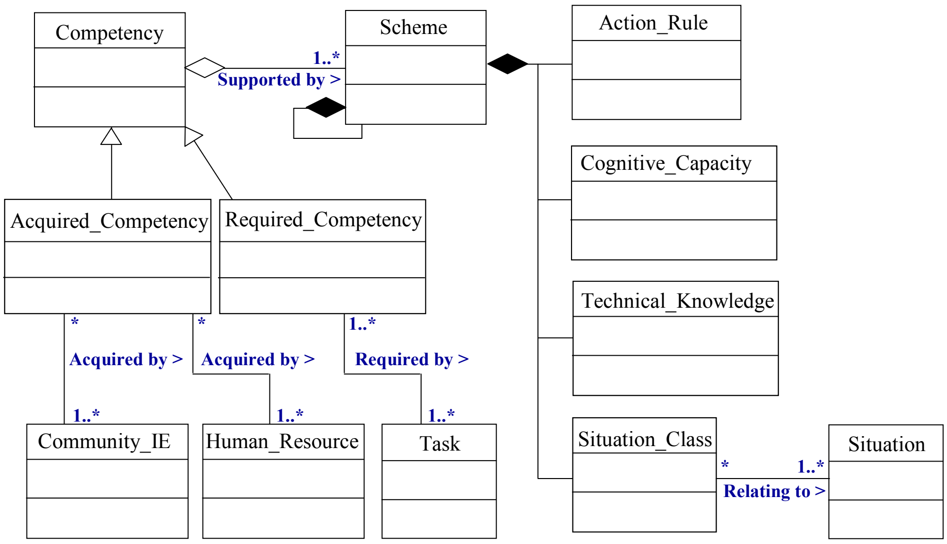

Figure 8: Global model of competence

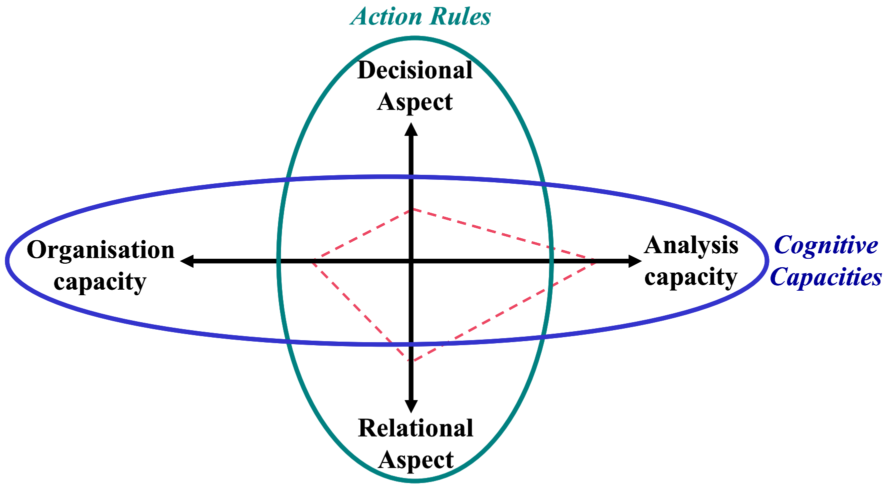

Figure 9: A cognitive signature of a competency

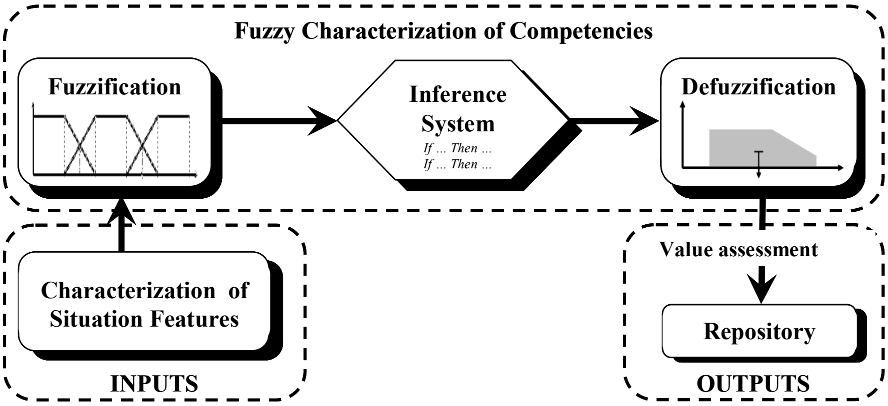

Figure 10: Fuzzy system of competency characterisation

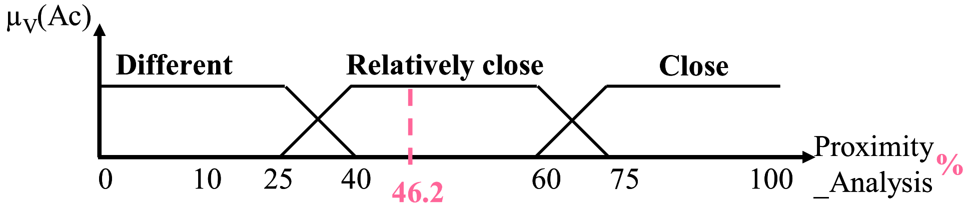

Figure 11: Membership function of the variable "Proximity / Analysis”

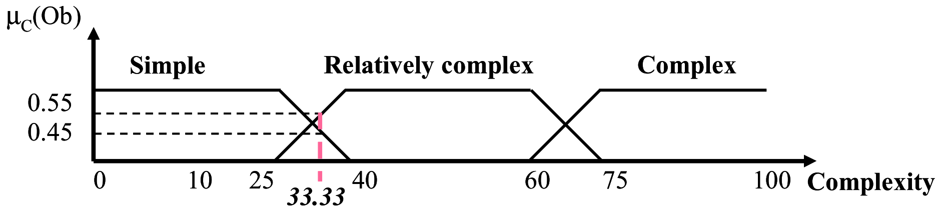

Figure 12. Membership function of the variable “complexity of the situation”

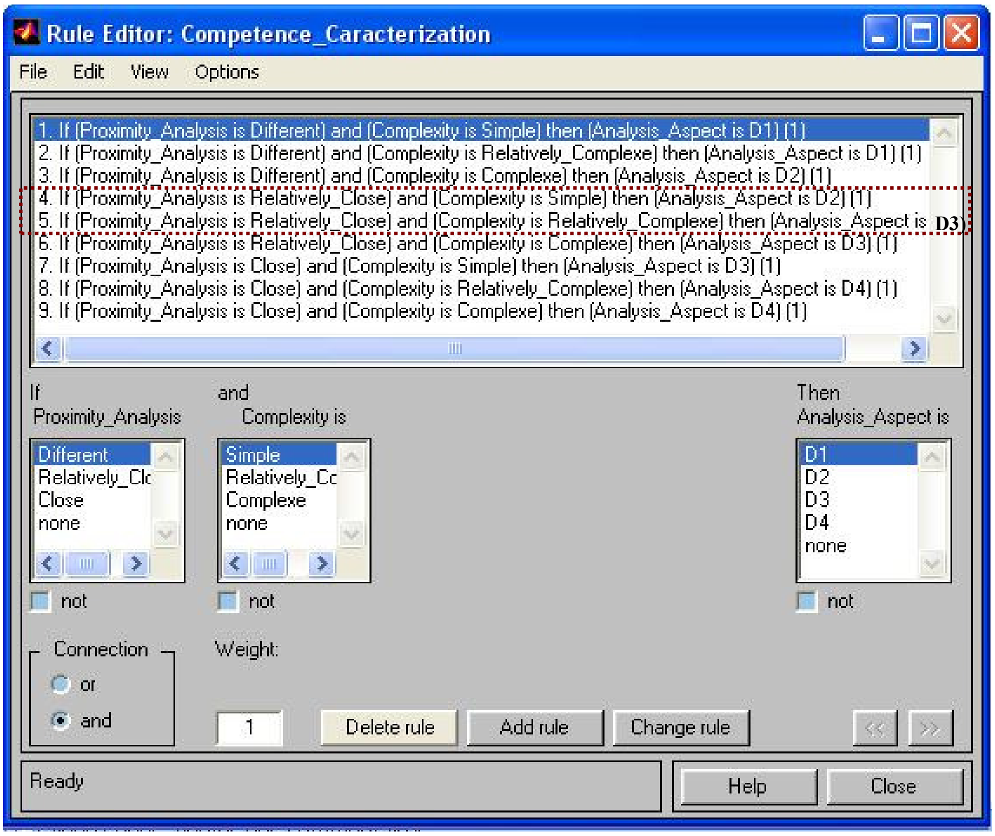

Figure 13. Inference rules

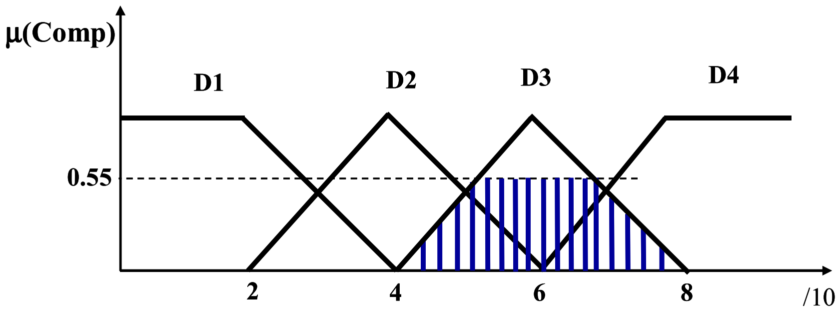

Figure 14. The membership function of the result of rule 5

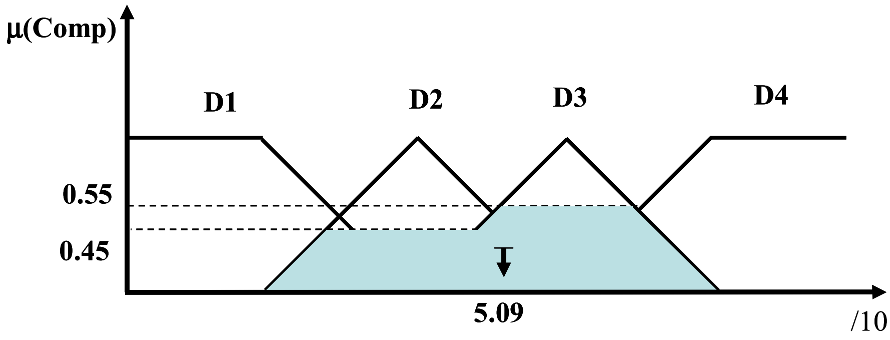

Figure 15: Assessed value of the "analysis level" after defuzzification

Table 1. Relationship between situation and competency

Situation features	Competency components
Entities in interaction during the activity and their roles in the IE	**Technical knowledge**
Nature of the activity Complexity of the main object treated by the activity	**Analysis capacity**
Complexity in relation to the total number of entities actually dealt with Complexity depending on the number of actions in an action plan	**Organisation capacity**
Nature of the activity Level of constraints	**Decisional aspect**
Main type of relationship Number of participants	**Relational aspect**